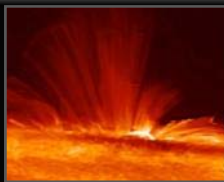


National Aeronautics and Space Administration



CM at NASA

marshall



[www.nasa.gov](http://www.nasa.gov)

Rajiv Doreswamy, Ph.D  
Deputy Implementation Manager, National Institute for Rocket  
Propulsion Systems,  
June 5, 2013

# CM at NASA

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NASA programs are characterized by complexity, harsh environments and the fact that we usually have one chance to get it right

Programs last decades and need to accept new hardware and technology as it is developed

We have multiple suppliers and international partners

Our challenges are many, our costs are high and our failures are highly visible

CM systems need to be scalable, adaptable to new technology and span the life cycle of the program (30+ years)

# International Space Station (ISS)

- First Element launch: Nov 1988
- Assembly Complete: May 2011
- Number of launches (May 2012):125
  - 81 Russian
  - 31 Space Shuttle
  - 1 Commercial
  - 3 Japanese
  - 3 European
- Orbital Mass: 420,000kg
- Overall length: 109m
- Software: 2 million lines (flight vehicle) + 3 million lines (ground systems)
- International Partners: NASA+ 14
- Multiple visiting vehicles: Shuttle, Soyuz, Progress ,ATV, HTV, Dragon, etc



# International Space Station (ISS)

## CM Lessons Learned

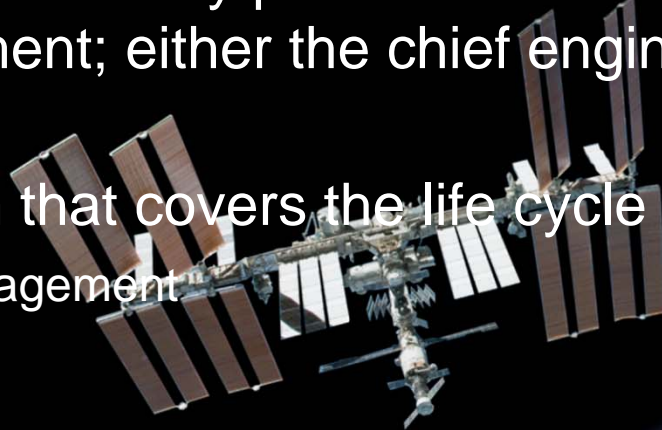
- Multiple Systems, Contractors and Countries added major levels of complexity to the ISS program and CM/DM and Requirements management systems
- CM Systems need to be designed for long design life
  - Space Station Design started in 1984
  - Assembly Complete in 2012
- Systems were developed on a task basis without an overall system perspective
- Technology moves faster than a large project office, try to make sure you have a system that can adapt





# Rajiv's Rules for CM

- Try to remember that your kids will be working on this system and will need to understand what you did
- CM is a key system for mission success, invest in it up front
- Focus on the functions, not on the tool
- CM manager must be a key part of the team and report to senior program management; either the chief engineer or planning and control manager
- Build a CM system that covers the life cycle of the project
  - Requirements Management
  - Conceptual Design
  - Final design
  - Test and verification
- Don't forget software CM!





Now that you have this great CM system, what are you going to use it for?

# NASA Priorities

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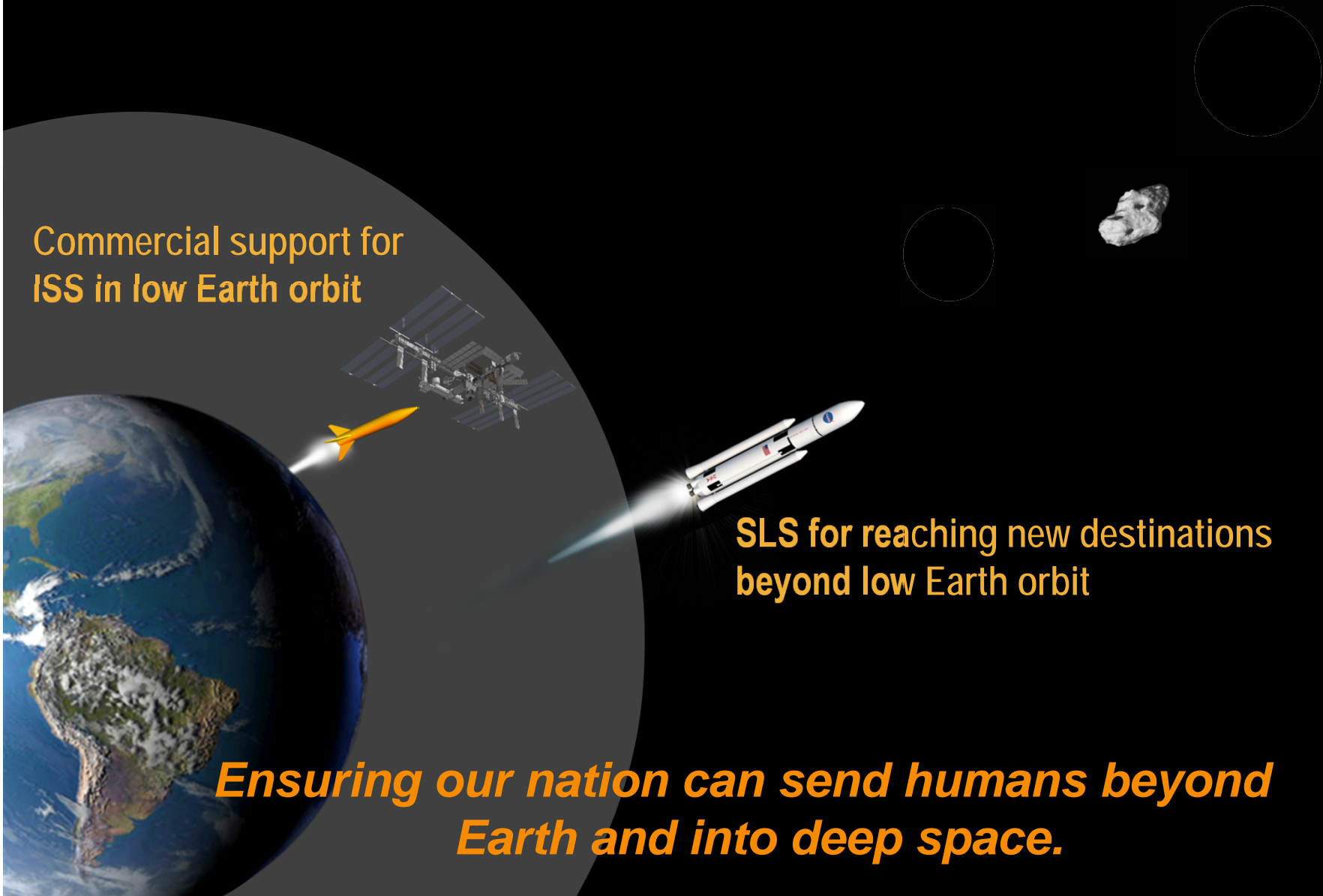
- Develop a capability to lift humans and high value payloads from Earth
  - Continue to live and work in Space, while extending human presence outside of Low Earth Orbit (LEO)
  - Build the ability and expertise to understand our planet and the universe beyond it
- 
- *NASA has the engineering expertise to ensure our nation can send humans beyond Earth and into deep space.*

# America's Human Spaceflight Architecture

Commercial support for  
ISS in low Earth orbit

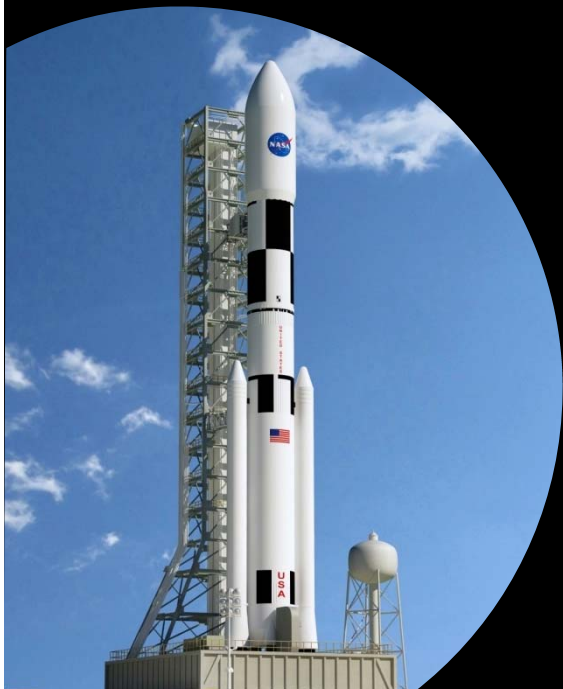
SLS for reaching new destinations  
beyond low Earth orbit

*Ensuring our nation can send humans beyond  
Earth and into deep space.*





# Lifting from Earth



## Space Launch System (SLS)

America's next heavy-lift rocket – sustainable and affordable

## Commercial Spaceflight

Partnering for success – sharing facilities and expertise

## Research for the Future

New fuels, new manufacturing and test methods, and advanced concepts



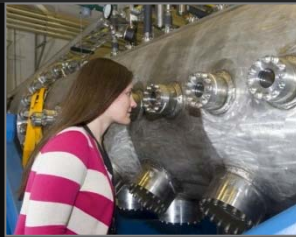
SLS – Block I  
(70-ton)



J2-X Engine Pack  
Testing



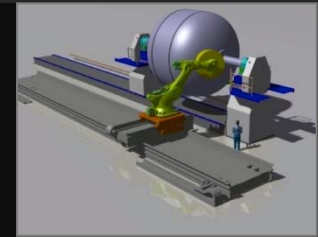
Supporting  
Commercial  
Spaceflight



Affordable Testing  
for Nuclear Fuel  
Prototypes



Collaborative  
Engineering Design



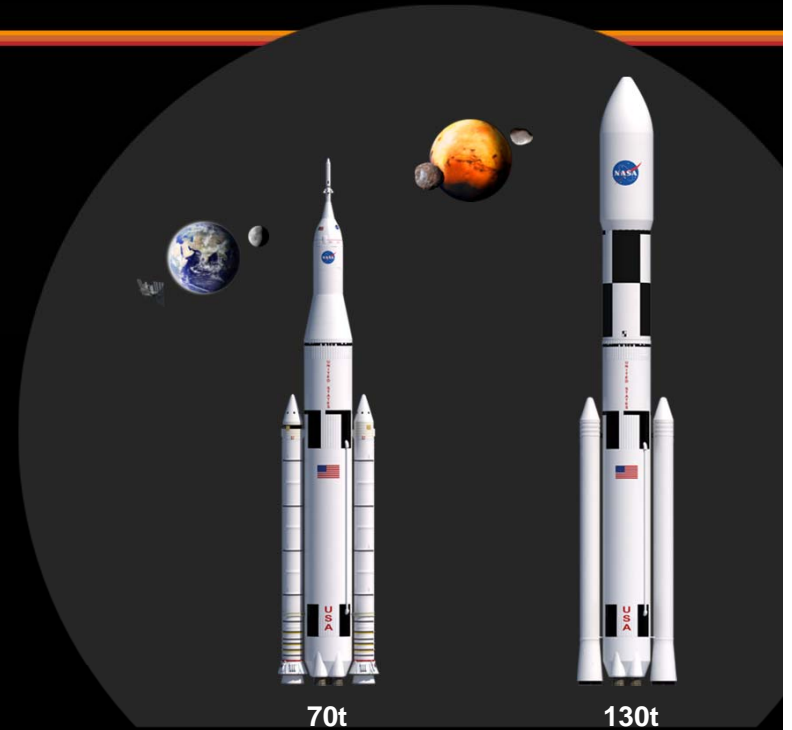
In-space Cryogenic  
Fuel Storage Concept

***Marshall is leading our nation's propulsion capabilities.***

# Lifting from Earth

## SLS – America's Heavy-lift Rocket

- Safe, affordable, and sustainable
- Carries the Orion Multi-Purpose Crew Vehicle
- Supports national missions beyond Earth orbit
- Initial lift capacity of 70 metric tons (t) evolving to 130 t
- Builds on Saturn, Shuttle, and Ares experience



Solid Rocket  
Motor Test



Friction Stir  
Welding



Shell Buckling  
Test



Upper Stage  
J-2X Engine



J-2X Engine  
Tests



Core Stage  
RS-25 Engines

*SLS is essential to the nation's space exploration goals.*

# Lifting from Earth



## **SLS – On track for a 2017 first flight**

- Key tenets: safety, affordability, and sustainability
- Progress being made on all elements of the vehicle
- Prime contractors on board, work being done across the country
- Completed System Requirements Review / System Definition Review, now working toward Preliminary Design Review in 2013
- Flight hardware being tested on EFT-1 in 2014
- Design Analysis Cycle (DAC) 2 configuration released

# Supporting U.S. Leadership in Propulsion Systems

# NIRPS

National Institute for  
Rocket Propulsion Systems

## Stewardship

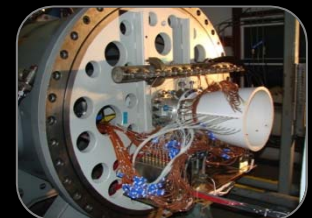
Formulate and recommend National Policy options and strategies that promote a healthy industrial base.

## Technology

Identify technology needs and recommend technology insertions.

## Solutions facilitator

Maintain relationships and awareness across the Government and industry to align available capacity with emerging demand.





# NIRPS: An Enabler for America's Space Endeavors

## Academia



Georgia Institute  
of Technology

UAHuntsville  
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

AUBURN  
UNIVERSITY

## Industry



ATK

AEROJET

Pratt & Whitney  
A United Technologies Company

USA  
United Space Alliance



## U.S. Government



NASA



FAA



DOD

# NIRPS

Fostering  
a vibrant rocket propulsion community  
that provides reliable and affordable propulsion systems  
in support of the nation's defense, civil, and commercial needs.

A composite image of space. The background is a dark blue and purple nebula. In the foreground, the curved horizon of the Earth is visible at the bottom. Above the horizon, the Moon is shown in a dark phase. Further up, a small white satellite or space station is visible. In the upper right, a reddish-orange planet is seen. The text "Our unique capability is in large scale, complex space systems development." is overlaid in orange.

Our unique capability is in large scale,  
complex space systems development.

Living and Working in Space

# Living and Working in Space

**Supporting Life in Space**

**Supporting Scientific Research on the International Space Station**



Lab Training Complex



Payload Operations  
Center



ECLSS testing  
at Marshall



Microgravity  
Science Glovebox



ISS U.S. Destiny Lab

***From large space structures to life support systems and operations, Marshall supports crews in space.***

# Living and Working in Space

## Supporting Life in Space

- International Space Station
  - Continual human presence since 2000
  - Completed in 2010
- Major U.S. nodes and modules
- Cleaning air and recycling water
- Environmental affects on people and materials



ISS Test Facility  
at Marshall



Node 3  
Tranquility



Delivery of the ISS  
Cupola



Atmosphere Resource  
Recovery and  
Environmental  
Monitoring



Multi-purpose  
Logistics Module,  
Leonardo



Environmental  
Control & Life  
Support System  
(ECLSS)

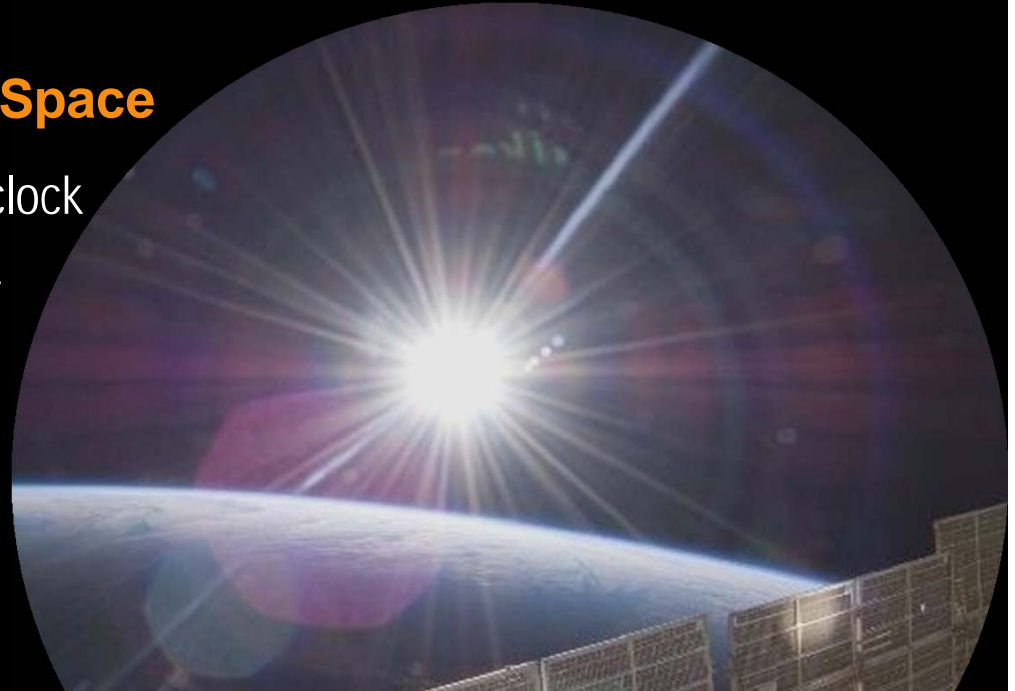
***Marshall develops systems for living and working on the ISS.***



# Living and Working in Space

## Supporting Scientific Research in Space

- Manage science operations around the clock
- Window Observational Research Facility
- Microgravity Science Glovebox
- Materials Science Research Rack



Payload Operations  
Center at Marshall



WORF – Window  
Observational  
Research Facility



EXPRESS Racks for  
Destiny Module



Materials Science  
Research Racks



Microgravity  
Science Glovebox



Destiny Laboratory

***Marshall is the command post for science on the ISS.***

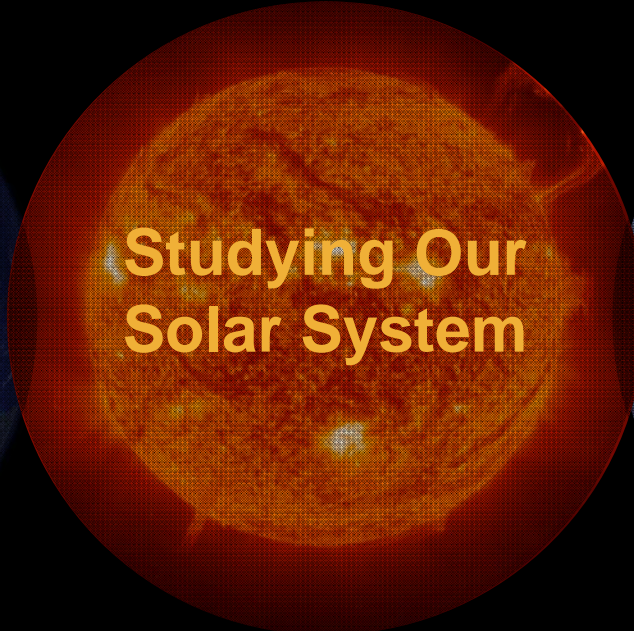
A composite image of space. In the foreground, the curved horizon of the Earth is visible, showing blue oceans and white clouds. Above the Earth, the Moon is shown in a dark, cratered phase. Further up, a small satellite or space station is visible against the backdrop of a vibrant nebula with blue and purple hues. In the upper right, a small, glowing orange planet or star is visible. The overall scene is set against a deep black space background with scattered stars.

We advance space technologies and expand our knowledge of the universe.

**Understanding Our World and Beyond**



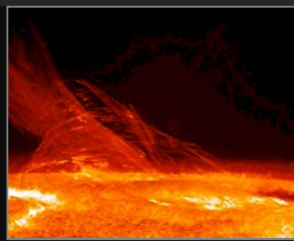
# Understanding Our World and Beyond



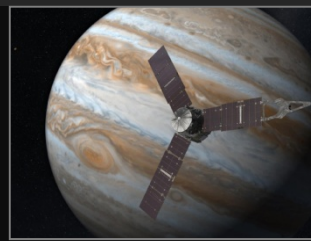
Weather & Climate  
Monitoring



SERVIR



SUMI Solar  
Capture



Discovery &  
New Frontiers



Chandra



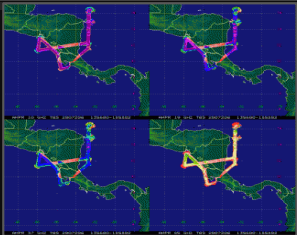
James Webb  
Space Telescope

***Marshall is expanding knowledge  
of our world and beyond.***

# Observing Earth



- Understanding global climate system patterns
- Improving weather forecasts and storm warning times
- Predicting the intensity and dynamics of storms
- Providing and analyzing data for urban planning and natural resource and environmental management



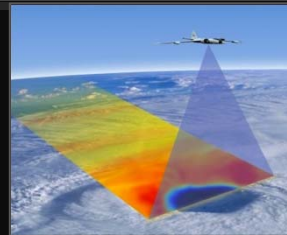
**AMPR**



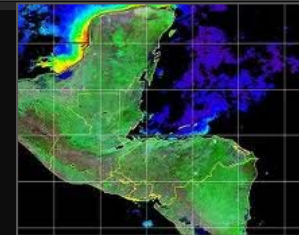
**Weather &  
Climate  
Monitoring**



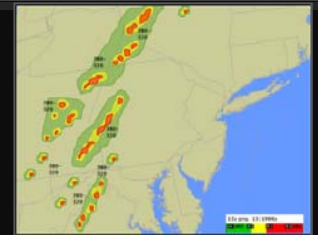
**PEOPLE - ACE**



**Hurricane  
Imaging  
Radiometer**



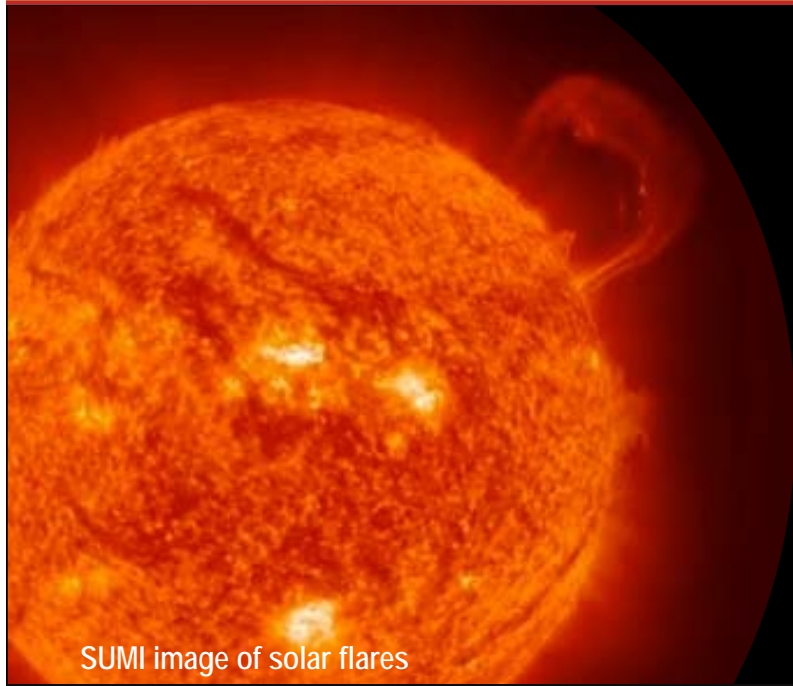
**SERVIR**



**SPoRT**

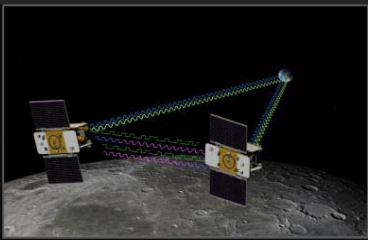


# Studying Our Solar System



SUMI image of solar flares

- Managing missions through our solar system to learn more about asteroids, planets, and their moons
- Developing robotic landers that can safely land on precise locations without human control
- Learning how the sun and space weather affect life on Earth
- Mapping the moon and measuring its gravitational field



\*GRAIL, twin spacecraft mapping the moon



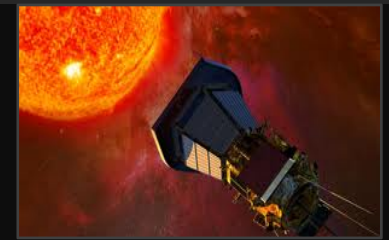
\*Asteroid Vesta from Dawn spacecraft



Robotic Lander autonomous landing test



Preparing SUMI for flight



Solar Wind, Electrons, Alphas, and Protons (SWEAP)

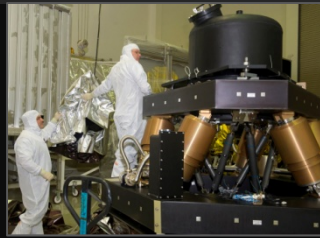
*\*Featured missions from the Discover and New Frontiers program, managed at Marshall.*

# Exploring the Universe Beyond

- Analyzing complex data from various space observation instruments
- Analyzing complex data from various space observation instruments
- Developing and testing optical systems for advanced deep-space telescopes applications
- Capturing visible and infrared light, gamma rays, and X-rays



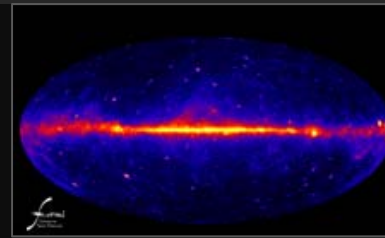
JWST mirror  
testing



JWST instrument  
testing



Cats Eye Nebula  
from Chandra X-ray  
Observatory



Fermi Gamma Ray  
Space Telescope map  
of the Gamma Ray sky



Omega Nebula  
from Hubble

A composite image of space. In the foreground, the curved horizon of Earth is visible at the bottom. Above it, the Moon is shown in a dark phase. Further up, a small satellite or space station is visible. In the upper right, a bright, orange-red planet is seen. The background is filled with a colorful nebula in shades of blue, purple, and red, with several stars scattered throughout.

Marshall supports NASA's mission.

**Technology – Goals – Benefits – Education**



# Proving Technology Readiness

## Advancing Space Technology Development

- Nuclear Cryogenic Propulsion Stage
- Atmosphere Resource Recovery and Environmental Monitoring (ARREM)
- Deep Space Habitat
- Radiation Protection
- In-Space Manufacturing
- Cryogenic Propellant Storage and Transfer
- Materials on ISS Experiments (MISSE)
- Robotic Lunar Lander Development (Mighty Eagle)
- Advanced Mirror Technology Development
- Edison Small Satellite
- Innovative Manufacturing
- In-Space Propulsion
- SWORDS
- Nuclear Systems
- Human-Robotic Systems
- Avionics Hardware
- Composite Cryogenic Propellant Tank
- Synthetic Biology

## Demonstrating Feasibility of New Technologies

- Technology Demonstration Missions – Level II Program Office
- Centennial Challenges Program –Level II Program Office



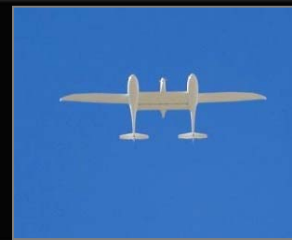
Cryo Propellant  
Storage



MISSE



Robotic Lander



Green Flight



Space Tether



Composite  
Cryotank



# The National Aeronautics and Space Administration



Science



Space  
Technology



Human Exploration  
and Operations



Aeronautics  
Research

***Marshall supports three of the NASA Mission Areas.***

# NASA and Marshall Strategic Goals

## NASA Agency

Extend and sustain human activities across the solar system.

Expand scientific understanding of the Earth and the universe in which we live.

Create innovative new space technologies for our exploration, science, and economic future.

Advance aeronautics research for societal benefit.

Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.

Share NASA with the public, educators, and students to provide opportunities to participate in our mission, foster innovation, and contribute to a strong economy.

## Marshall Space Flight Center

Develop and operate integrated vehicles and systems to enable human space activities.

Develop, integrate, and operate instruments and conduct research to expand knowledge of the universe.

Develop, test, and mature new space technologies to enable NASA missions and benefit the Nation.

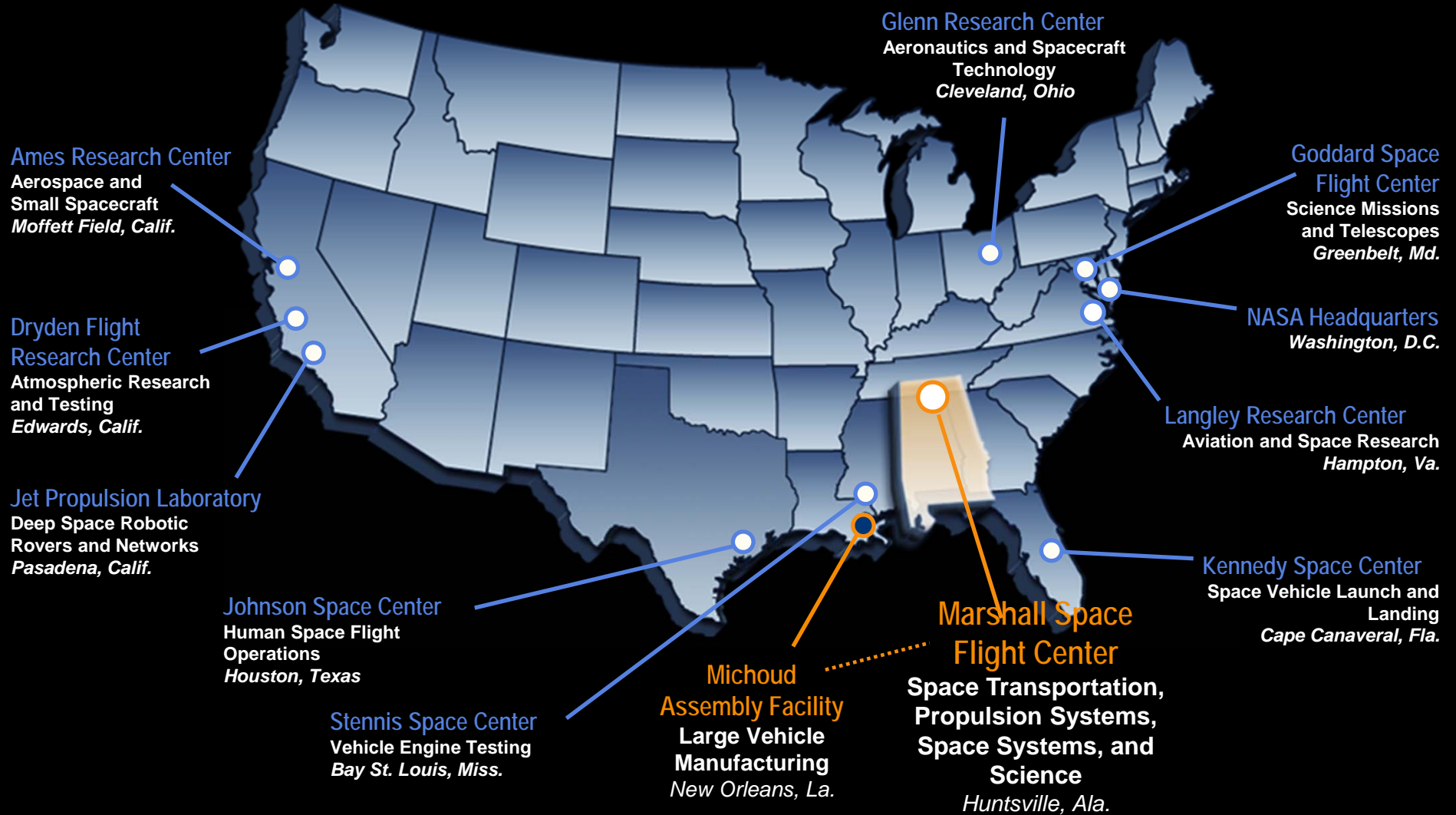
Marshall does not programmatically support aeronautics.

Provide and manage program, project, and institutional capabilities to conduct NASA's and Marshall's space activities.

Share NASA and Marshall with the public, educators, and students to foster communication, participation, and innovation to benefit the interests of the Nation.

***Marshall's work aligns with five of the six agency strategic goals.***

# NASA Around the Country



**Supporting NASA's mission with unique engineering expertise.**



# Benefitting Life on Earth - Technology Spinoffs



High-pressure fire  
hose nozzles

Technologies developed  
at Marshall touch our lives  
in many ways.



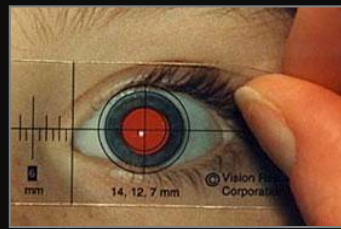
Weather & Climate  
Monitoring



Nextel™ Flame  
Stopping Dot  
Paper



Kevlar™ Body  
Armor



Improving Vision  
Screening



Healing  
Treatments



Water Filtration  
Systems

***Science and exploration improves our lives and our planet.***



# Science, Technology, Engineering and Math (STEM)



Marshall reaches out to all ages to encourage STEM educations and careers.



Outreach Activities



Observe the Moon Night



Student Launch Projects



Moonbuggy Race



Co-op and Intern Programs



***Marshall is inspiring a new generation of explorers.***

# NASA Centers' Regions for Public Outreach



NASA Headquarters



Ames Research Center



Dryden Flight Research Center



Glenn Research Center



Goddard Space Flight Center



Jet Propulsion Laboratory



Johnson Space Center



Kennedy Space Center



Langley Research Center



Stennis Space Center



Marshall Space Flight Center



Michoud Assembly Facility



A cosmic background image featuring the Earth's horizon at the bottom, the Moon in the center, and Mars in the upper right. A vibrant nebula with blue and red hues is visible in the upper left. The text "Marshall in the Community" is overlaid in orange.

Marshall in the Community

**Marshall Profile**



# Marshall Profile



**\$2.3B expenditures  
nationally (FY2011)**  
\$1.2B in Alabama



**Nearly 6,000 employees**  
(FY12 2,490 civil service)



**2<sup>nd</sup> largest employer**  
in the Huntsville – Madison  
County area

**26 core capabilities and more than 125  
unique and specialized facilities and labs**



## **Part of a technological community**

Redstone Arsenal – home to 22 primary  
federal/international organizations

Cummings Research Park –  
2<sup>nd</sup> largest in U.S. and 4<sup>th</sup> largest in the world

Huntsville's concentration of high-tech  
workers is 2nd in the nation

***Marshall impacts the community.***





[www.nasa.gov/marshall](http://www.nasa.gov/marshall)